

**Chapter 11**

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These are answers to the exercises in Chapter 11 of:

*Understanding the Properties of Matter*  
by Michael de Podesta.

If you find an error in these answers, or think they could be clarified in any way, please feel free to contact me.

Thanks

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C1. From Table 11.2 find out which element has:

(a) Carbon, C has  $\approx 3700$  K (but does it melt or sublime?)

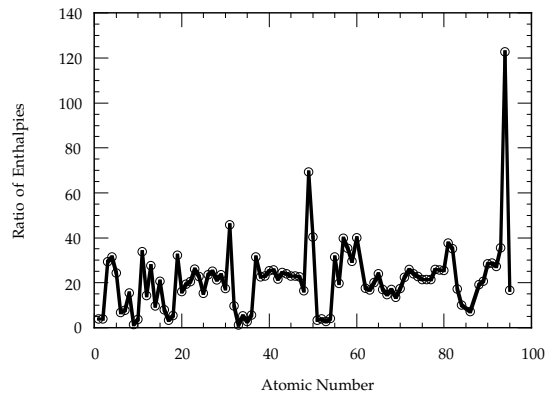
Tungsten, W has 3680 K

(b) Tantalum, Ta has 3269 K from the Figure

(c) Silicon  $39.6 \text{ kJ mol}^{-1}$  or (Carbon  $105 \text{ kJ mol}^{-1}$  if it melts)

(d) Tungsten  $799.1 \text{ kJ mol}^{-1}$

(e) Plutonium, followed by the low melting point elements Indium and then Gallium. i.e. these elements form liquids relatively easily. Ones with a low ratio form liquids only with 'difficulty'.

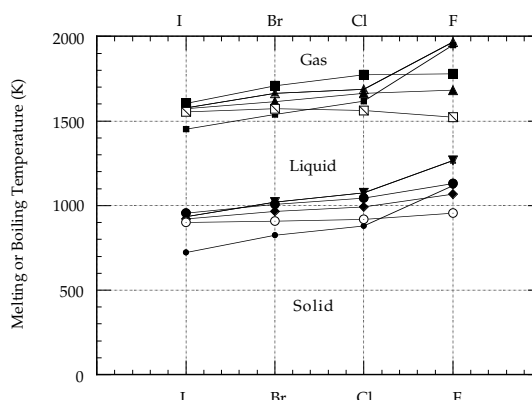


P2. Probably the boiling temperature. From Table 11.2, estimate W with  $T_B \approx 5680$  K and verified in Table 11.5.

P3. The boiling temperature of (a) methanol is 337.7 K (b) ethanol is 351.5 K (c) acetone 329.3 K

**P4.**

The melting and boiling temperatures of the alkali halides show weak systematic variation with the member of the halide family involved. The relatively sharp change with F compounds is due to the different crystal structure caused by the larger difference in ion size. The weak variation of melting temperature and boiling with components is what you would expect from the discussion of ionic and covalent bonding in § 6.2, because there it was just the charge on the ion that we considered, when calculating the cohesive energy, and this ionic charge is the same for the compounds above. Some degree of an increasing degree of covalency is the main factor responsible for the small systematic changes with halide.

**P5. P6. P12. & P13.**

Units  $\text{J kg}^{-1}$

	P5. & P6. To melt 1kg	P12 To melt 1kg. & P13. To boil 1kg
(a) helium	$0.021 \times 10^3 / 4 \times 10^{-3} = 5.25 \times 10^3$	$0.082 \times 10^3 / 4 \times 10^{-3} = 0.021 \times 10^6$
(b) neon	$0.324 \times 10^3 / 20.18 \times 10^{-3} = 16.06 \times 10^3$	$1.174 \times 10^3 / 20.18 \times 10^{-3} = 0.058 \times 10^6$
(c) argon	$1.21 \times 10^3 / 39.95 \times 10^{-3} = 30.29 \times 10^3$	$20.40 \times 10^3 / 39.95 \times 10^{-3} = 0.511 \times 10^6$
(d) krypton	$1.64 \times 10^3 / 83.8 \times 10^{-3} = 19.5 \times 10^3$	$9.05 \times 10^3 / 83.8 \times 10^{-3} = 0.108 \times 10^6$
(a) copper	$13 \times 10^3 / 63.55 \times 10^{-3} = 204.6 \times 10^3$	$304.6 \times 10^3 / 63.55 \times 10^{-3} = 4.79 \times 10^6$
(b) silver	$11.3 \times 10^3 / 107.9 \times 10^{-3} = 104.73 \times 10^3$	$255.1 \times 10^3 / 107.9 \times 10^{-3} = 2.36 \times 10^6$
(c) gold	$12.7 \times 10^3 / 197 \times 10^{-3} = 64.5 \times 10^3$	$324.4 \times 10^3 / 197 \times 10^{-3} = 1.65 \times 10^6$
(d) mercury	$2.331 \times 10^3 / 200.6 \times 10^{-3} = 11.6 \times 10^3$	$59.15 \times 10^3 / 200.6 \times 10^{-3} = 0.295 \times 10^6$

**P7.** Mostly OK, but when wrong it can be very wrong! i.e. not reliable

**P8.** Slope of curve  $\approx 2.624 \times 10^{-8} \text{ K Pa}^{-1}$  so at 1.1 Bar  $\Delta T_M \approx 2.6 \times 10^{-4} \text{ K}$

**P9.**  $f = 0.061$  lies well within the 1 standard deviation limits drawn on Figure 11.7.

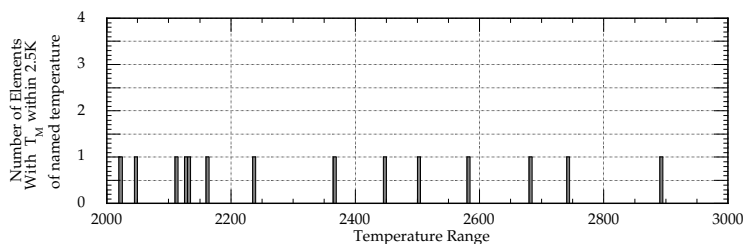
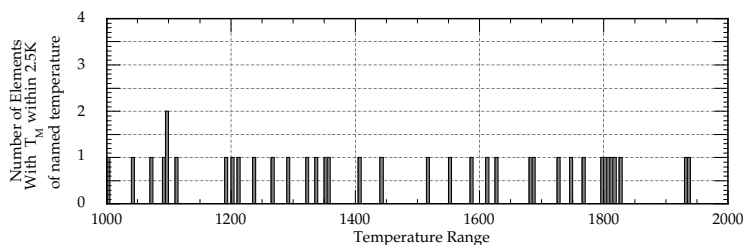
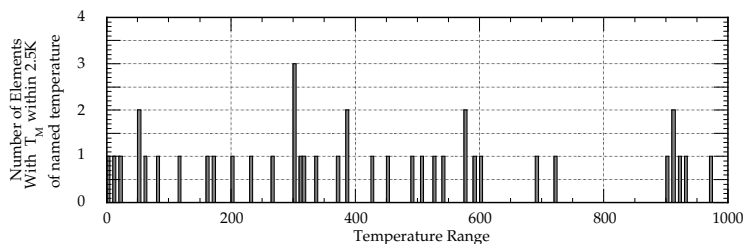
**P10.** Estimates are that  $L_V/T_B \approx 0.1$  and  $L_M/T_M \approx 0.01$

	$T_M$	$T_M \times 0.01$	$L_M$	$T_B$	$T_B \times 0.1$	$L_V$
Silicon	1683	16.83	39.6	2628	262.8	383
Copper	1357	13.57	13	2840	284.0	304.6
Tungsten	3680	36.80	35.2	5930	593.0	799.1

Estimates are not bad ballpark guesses. The poor agreement for silicon is because liquid formation is

inhibited in covalently bonded substances.

**P11.** Knowing the melting temperature determined with an uncertainty of  $\pm 3$  K identifies an element rather well (See Histograms below). When there is some uncertainty, one other physical measurement e.g. density will usually resolve any uncertainty.



**P12. & P13.** (See P5. & P6.)

**C14.** Typographical error in Table for Acetone and in Equation 11.16 where  $\Delta E\rho$  should be  $\Delta E_e$

Using Data for  $10^4$  and  $1.013 \times 10^5$  Pa only we find answers below based on Equation 11.16. For  $P = 10^4$  we have  $T_4$  and for  $P = 10^5$  we have  $T_5$  i.e.

$$\ln\left(\frac{10^4}{T_4}\right) = \left[ \right] - \left( \frac{-\Delta E_e}{k_B T_4} \right)$$

$$\ln\left(\frac{10^5}{T_5}\right) = \left[ \right] - \left( \frac{-\Delta E_e}{k_B T_5} \right)$$

$$\ln\left(\frac{10^4}{T_4} \frac{T_5}{10^5}\right) = \left( \frac{\Delta E_e}{k_B} \right) \left[ \frac{1}{T_5} - \frac{1}{T_4} \right]$$

$$L = \Delta E_e N_A = \left[ \frac{1}{T_5} - \frac{1}{T_4} \right] \ln \left( \frac{T_5}{10T_4} \right)$$

Since Water has  $L = 40.608 \text{ kJ mol}^{-1}$ , these numbers look about right...

Substance		MW	T (K) for $P=10^4 \text{ Pa}$	Boiling Point (K)	L (kJmol <sup>-1</sup> )
Acetic Acid	CH <sub>3</sub> COOH	60	329	391.1	36.67
Acetone	CH <sub>3</sub> COCH <sub>3</sub>	58	349	329.3	-114.44
Aniline	C <sub>6</sub> H <sub>7</sub> N	93	385	457.6	42.95
Benzene	C <sub>6</sub> H <sub>6</sub>	78	293	353.2	30.22
Chloroform	CHCl <sub>3</sub>	119	278	334.4	29.01
Cyclohexane	C <sub>6</sub> H <sub>10</sub>	82	292	353.8	29.32
Ethyl Acetate	C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	88	294	350.2	32.39
Methanol	CH <sub>3</sub> OH	32	288	337.7	34.85
Ethanol	C <sub>2</sub> H <sub>5</sub> OH	46	302	351.5	38.33
Propan-1-ol	C <sub>3</sub> H <sub>7</sub> OH	60	320	370.3	42.22
Propan-2-ol	C <sub>3</sub> H <sub>7</sub> OH	60	307	355.4	40.39
Butan-1-ol	C <sub>4</sub> H <sub>9</sub> OH	74	338	390.35	45.21
Butan-2-ol	C <sub>4</sub> H <sub>9</sub> OH	74	322	372.65	42.45
Toluene	C <sub>7</sub> H <sub>8</sub>	92	318	383.8	32.59

**P15.**

	Tc(K)	Pc (MPa)	Vc(×10 <sup>-6</sup> )m <sup>3</sup>	ρ(kgm <sup>-3</sup> )	
(a) water	647.3	22.12	59.1	304.57	≈0.3
(b) carbon dioxide	304.2	94	7.38	468.09	≈
(c) ethanol?	513.9	167	6.14	275	≈0.35

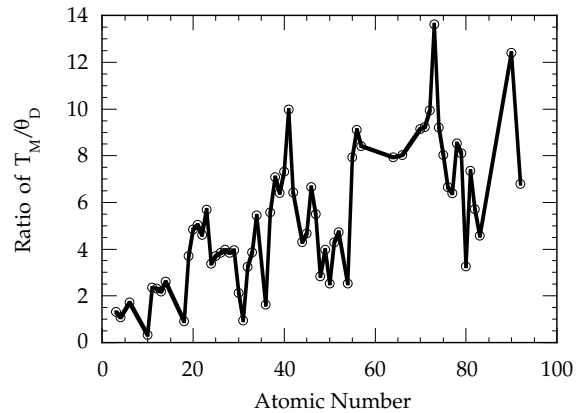
**P16.** Volume per molecule of water in

(a) its critical state:  $V_c = 59.1 \times 10^{-6}$  so volume per molecule =  $9.81 \times 10^{-29} \text{ m}^{-3}$

(b) its liquid state:  $V_c = 18.0 \times 10^{-6}$  so volume per molecule =  $2.98 \times 10^{-29} \text{ m}^{-3}$

**C17.** Very roughly  $T_C \approx 3/2 T_B$  and  $T_M \approx 2/3 T_B$

**C18.**



No clear rule, but maybe  $T_M \approx 5 \times \theta_D$ , but large fluctuations present

**P19.** Predict the Debye temperature of copper based on the melting temperatures of copper, 1357

silver            225      1235      0.1821    predicts 247.2 for Copper

gold              165      1337      0.1234    predicts 167.4 for Copper

Actual value is  $\approx 340$  i.e  $T_M$  is a poor predictor for the debye temperature

**P20.** Identify the elements in Figure 11.27 which have anomalously low boiling points for their cohesive energy. How have these anomalies arisen? Explain why their existence does not invalidate the general correlation of boiling temperature and cohesive energy?

**P21.**

	ice	water
(i) 0 °C,	610.6 Pa	610.6 Pa
(ii) -10 °C	260.0 Pa	286.5 Pa
(iii) -20 °C	103.4 Pa	—

Yes! When its cold! Especially just below freezing.

**P22.** In the solid, molecules from below the surface are not able to wiggle their way to the surface in order to leave. Might try studying the vapour pressure above nanometre size ice particles, or ice thin films.

**P23.** (a) 273.16 K (exactly) (b) 83.8058 K

**P24.** No answer available at the moment. sorry.

**P25.**

Figures 11.31 and 11.32 arise from changes of state of different types of order within the solid, and we do not call them latent heat. They form “smeared” out versions of the graph shown opposite.

